Acta Tropica 172 (2017) 132–138

Contents lists available at ScienceDirect

Acta Tropica

journal homepage: www.elsevier.com/locate/actatropica

Establishment of first engineering specifications for environmental modification to eliminate schistosomiasis epidemic foci in urban areas

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ARTICLE INFO

Keywords:
Schistosomiasis
Snail control
Environmental modification
Mollusciciding
Engineering
Urban areas

ABSTRACT

Snail control is a key link in schistosomiasis control, but no unified methods for eliminating snails have been produced to date. This study was conducted to explore an engineering method for eliminating *Oncomelania hupensis* applicable to urban areas. The engineering specifications were established using the Delphi method. An engineering project based on these specifications was conducted in Hankou marshland to eliminate snails, including the transformation of the beach surface and ditches. Molluscicide was used as a supplement. The snail control effect was evaluated by field investigation. The engineering results fulfilled the requirements of the design. The snail density decreased to 0/0.11 m^2, and the snail area dropped to 0 m^2 after the project. There was a statistically significant difference in the number of frames with snails before and after the project ($P < 0.05$). Snails were completely eliminated through one year of continuous monitoring, and no new snails were found after a flood disaster. This study demonstrates that engineering specifications for environmental modification were successfully established. Environmental modification, mainly through beach and ditch remediation, can completely change the environment of *Oncomelania* breeding. This method of environmental modification combined with mollusciciding was highly effective at eliminating snails.

1. Introduction

Schistosomiasis is widely distributed throughout the world and remains a serious public health problem in many countries (Li et al., 2000). Schistosomiasis mainly spreads in the developing countries of Africa, Asia and South America, which are poor and agriculturally based, and at least 90% of the world's patients live in Africa (Dawaki et al., 2015; Hotez and Kamath, 2009; Vicente et al., 2016). According to WHO statistics, 240 million people in 78 countries are currently infected with schistosomiasis, and 779 million people are at risk of infection (PJ and G, 2009; WHO, 2002; Yang et al., 2015), making the burden of disease 70 million disability-adjusted life years (King and Dangerfield-Cha, 2008). With the growth of immigration and a continuously changing environment, the global schistosomiasis epidemic is going to produce a more serious disease burden and economic loss in the future (Fang et al., 2008; Finkelstein et al., 2008; King et al., 2005; van der Werf et al., 2003).

The prevalence of schistosomiasis is strongly related to social and economic conditions (Gazzinelli et al., 2006). Schistosomiasis in rural areas has been the focus of research and governance for many years. In contrast, research in cities is very rare, and the content and scope of the research are relatively concentrated (Firmo et al., 1996). Migration from rural to urban environments is prompting the constant expansion of urban schistosomiasis. At present, urban imported schistosomiasis infection occurs frequently throughout the world, and the residual snails breed often. Urban schistosomiasis is becoming an increasingly serious public health problem (HZ, 2002; Mott et al., 1990). Some studies have indicated that urban areas in Africa and South America have become foci of schistosomiasis transmission (Blanton et al., 2015; Mott et al., 1990).

The eradication of schistosomiasis must involve simultaneous transmission control and drug treatment. Snail control is a necessary method to achieve transmission control, especially in low-prevalence areas, and the final elimination of schistosomiasis can only occur through snail control (Sokolow et al., 2016; WHO, 1985; Yuan et al., 2005). Environmental modification, a long-term snail control method, has a more consolidated effect than other methods, and it saves resources and produces limited environmental pollution (YY et al., 2006). After an analysis of geographical conditions and economic capacity, this method is very suitable for the prevention and control

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http://dx.doi.org/10.1016/j.actatropica.2017.04.031
Received 18 January 2017; Received in revised form 28 April 2017; Accepted 29 April 2017
Available online 06 May 2017
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of schistosomiasis in urban areas. Schistosomiasis in China is caused by *Schistosoma japonicum*. *Oncomelania hupensis*, its unique vector, is operculate and amphibious. In China, 5 of 12 provinces have eliminated schistosomiasis japonica through a method combining environmental modification and mollusciciding (Chen, 1999). Combined with health education, treatment and prevention measures, the improvement of sanitation and the water supply system on the basis of environmental modification and mollusciciding will achieve a better transmission control effect (Li et al., 2007).

Previous environmental modification projects have achieved remarkable snail control effects (Ault, 1994; Xu et al., 2015), but these methods have not been widely used globally. There are no unified engineering technical routes and engineering standards due to an ineffective interdisciplinary combination of schistosomiasis control and engineering technology. Even worse, schistosomiasis control studies are at a serious stage of stagnation in large and medium-sized cities. According to the survival characteristics of *Oncomelania hupensis*, this study was devoted to the exploration of engineering specifications for environmental modification in schistosomiasis epidemic foci to eliminate *Oncomelania hupensis*. This method could be widely applied to large and medium-sized cities after being scientifically adjusted for different geographical features.

2. Materials and methods

2.1. Study site and population

Hankou marshland, the largest river beach cultural park in Asia, is located in Wuhan City, Hubei Province, China. This marshland, which is adjacent to the Yangtze River, is 8.45 km in length with an area of 1.6 million square meters. Hankou marshland is divided into two parts by the river embankment. The upper part is an artificial park suitable for leisure and entertainment. The lower part comprises a beach, reeds and weed growth. The natural scenery of the lower part attracts many visitors, who enjoy strolling along the widely distributed small paths. Tens of millions of Chinese residents and foreign tourists have traveled to Hankou marshland every year since it opened. However, this site is also a historical snail marshland area. The effects of flooding have produced an upstream development trend in the snail distribution, which poses a great threat to the health of the residents and visitors near the river.

2.2. Research design

First, the engineering specifications were established using the Delphi method. Then, their effectiveness was verified by engineering practice. The implementation of the project was divided into three stages: risk assessment, environmental modification and evaluation of the effects of snail control. This project, combined with a comprehensive strategy led by the government, could achieve significant effects on schistosomiasis control (Fig. 1), such as treatment and prevention measures, health education, and improvement of sanitation and water supply systems.

2.3. Risk assessment

The objective of this study's risk assessment was to assess the risk of acute schistosomiasis infection in the study area. First, a field investigation was conducted to monitor the risk of schistosomiasis. (Field investigations were approved by the Centers for Disease Control and Prevention, Jiangan, Wuhan. Each field investigation was followed by CDC technicians.) During the field investigation, a Google Earth-based global positioning system and geographic information system were used to pinpoint the locations of *Oncomelania hupensis* and describe their geographical features to show their overall distribution and infection in the spring and autumn of 2013 (Sun et al., 2011; Zhang

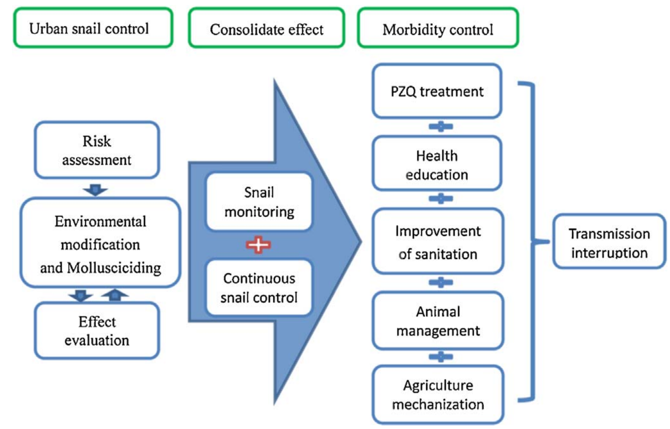

Fig. 1. Model for urban schistosomiasis control. The model was adjusted according to the integrated control strategy of schistosomiasis. The method of snail control is emphasized.

et al., 2006). Each survey unit was a square 0.11 m^2 in area with a side length of 33.33 cm. The snail density was defined as follows:

$$D = \frac{S}{F}$$

where D is the snail density (the unit is a number/0.11 m^2), S is the number of snails, and F is the number of frames.

Because mouse feces were the most widely distributed wild feces in the marshland, we divided all the wild feces into mouse feces and other wild feces. Wild feces were collected using a grid method, with 20 m × 20 m as a survey unit and every two survey units separated by 20 m (Chu, 2010; Zuo et al., 2016). Based on the results of the field investigation, the numeric values of all the parameters were obtained by the Delphi method, including harmfulness (A, 0–10, referring to the impact of the occurrence of acute schistosomiasis infection), the possibility of acute infection (B, 0–10, referring to the probability of the occurrence of acute schistosomiasis infection) and the level of uncontrollability (C, 0–1, referring to the possibility that the risk could not be controlled) (Huang, 2011; Ying et al., 2015). The risk value was calculated based on the formula Z = A × B (where Z is the risk value, which refers to the degree of harm to the population) (Huang, 2011). The risk value and the parameter C were correspondingly added to the risk matrix (X et al., 2013; ZY et al., 2015). According to its position in the matrix, the final risk was divided into 4 levels.

2.4. Environmental modification

The initial engineering indicators and standards were selected using a systematic analysis and literature data analysis. Then, the engineering indicators and their standards were further developed using the Delphi procedure. After three rounds of the Delphi procedure, the final engineering specifications were determined. The Delphi procedure synthesizes the opinions of experts with the available evidence to provide a detailed assessment. The engineering specifications presented a complete set of engineering technical routes and engineering standards. The engineering process included 4 steps: eradicating reeds and high bar plants, topsoil stripping and landfill, topsoil cover, and digging of new ditches and filling of old ones (Fig. 2).

First, the reed land was turned over repeatedly by machines to clear out the reed roots (A et al., 2005; Zhang et al., 2013). Then, the soil with snails was removed through topsoil stripping to a thickness of 20 cm. The topsoil with snails was dumped in nearby ditches or low-lying land, and then the surface was covered with soil without snails at a thickness of more than 30 cm (Lu et al., 2011). The excess soil without snails was buried nearby at a thickness that did not exceed 15 cm (Chen et al., 2009; Lin et al., 2015; Wang et al., 2007). After the transformation of the beach surface was complete, it formed a slope not less than

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